GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ____

Project No. E-25-625 GTRI/~~GIT~~ DATE 5 / 10 / 84

Project Director: W. O. Winer and S. Bair School/~~Lab~~ ME

Sponsor: Continental Group, Augusta, GA

Type Agreement: Standard Project Agreement E-25-625, dated 3/27/84

Award Period: From 3/27/84 To 3/26/85 (Performance) 3/26/85 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated:	$ 55,000	$ 55,000
Funded:	$ 55,000	$ 55,000

Cost Sharing Amount: $ None Cost Sharing No: N/A

Title: Rheology of Coating Colors

ADMINISTRATIVE DATA OCA Contact William F. Brown X4820

1) Sponsor Technical Contact:

2) Sponsor Admin/Contractual Matters:

Mr. W. H. Wiseman, VP & Gen. Mgr.
Continental Group
Bleached System Operations
Highway 56 Sough
P. O. Box 1425 (13)
Augusta, GA 30913
(404) 798-5711

Defense Priority Rating: None Military Security Classification: None

(or) Company/Industrial Proprietary: ____

RESTRICTIONS

See Attached --- Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GTRI

COMMENTS:

COPIES TO:

Sponsor I. D. #02.252.000.84.001

Project Director (Winer/Bair)
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
~~Research Security Services~~
(Reports Coordinator (OCA))
Research Communications (2)
GTRI
Library
Project File
Other ____

FORM OCA 4:383

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 12/18/84

Project No. E-25-625 School/~~Lab~~ XXX ME

Includes Subproject No.(s)

Project Director(s) W. O. Winer & S. Bair GTRI / ~~GIT~~ XXX

Sponsor Continental Group - Box 1425 - Augusta, GA 30913

Title Rheology of Coating Colors

Effective Completion Date: 12/15/84 (Performance) 12/15/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [X] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. N/A Continued by Project No. N/A

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services

Library
GTRI
Research Communications (2)
Project File
Other A. Jones; M. Heyser

Form OCA 60:1028

Georgia Institute of Technology
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF MECHANICAL ENGINEERING
ATLANTA, GEORGIA 30332

24 July 1984

Dr. W. H. Wiseman
Vice President and General Manager
Continental Group
Bleached System Operations
Highway 56 South
P.O. Box 1425 (13)
Augusta, Georgia 30913

Dear Bill:

Enclosed please find our quarterly progress report on Rheology of Coating Colors. If there are any questions please call.

Sincerely yours,

Scott Bair
Research Engineer

jmv

xc: W. O. Winer
J. H. Wing
Dennis Huang

Rheology of Coating Colors

Progress Report

for the First Quarter

[27 March 1984 through 26 July 1984]

During the first quarter of the Georgia Tech/Continental Rheology of Coating Colors research program substantial progress has been made in two areas: in the definition of the paper printability problem and in the rheological characterization of the coating colors.

Problem Definition

Printability of coated paper is being determined at Continental by performing a quality control gravure printing on paper samples. Coated surface quality is judged by noting printing defects, a defect being a missing print dot where ink failed to transfer to the paper.

Profiles of the surface geometry were taken of a printed test card with a Bendix profilometer and recorded on a digital scope to be plotted later. Surface modification by the profilometer stylus was found to be minimal compared to the paper surface features. During the profile measurement the card was viewed through a microscope at a 30^{o} angle to the surface. A second channel in the digital scope was used to record the passage of the stylus over a printed dot or a missing dot. A profile is shown in Figure 1 where the upper curve indicates the presence of printing and the lower curve the surface features.

A survey of many such profiles indicates that print defects occur when a dot would have been positioned inside a depression 0.1 to 0.5 mm wide and greater than 3 μm deep.

A Fast Fourier Transform computer program was used to develop a roughness frequency spectrum from very long (25 mm) profiles of both coated and uncoated paper samples from paper machine number 1 (PM1). Accelerometer data from PM1 provided by Continental shows a peak in the vibration spectrum at a wavelength of 3 mm. No increase in roughness at or near a wavelength of 3 mm was observed from uncoated to coated paper. This indicates, assuming that our samples were coated at approximately the same paper speed, that blade vibration is not contributing to coating roughness. It is more likely that the roughness of the substrate drives the vibration of the blade. In addition, if blade vibration were contributing to printing defects one would expect defects to be oriented in rows perpendicular to paper motion, that is, along the blade direction. However, the depressions which cause defects are approximately circular.

Many photomicrographs were made of printed test cards viewing vertical to the surface and illuminated at a low angle to the surface to document the appearance of depressions which cause print defects.

In addition, glass slides were coated to controlled thicknesses of 25 to 125 μm by doctoring color from the slide with a shim steel blade. Two shims (one along either side of the slide) controlled thickness. The drying of the coating was observed through a microscope and in one case recorded on video tape. Evident in each case was the existence of bubbles in the liquid color even after the bulk liquid stood undisturbed for several weeks. The bubbles

were evident in the coating on the slide when the slide was viewed with transmitted light from beneath. Some bubbles which are just below the surface rupture, leaving a cavity. Some, well below the surface, leave a depression on the surface above as the coating dries. Profiles taken over bubbles of the dry coated slide have features similar to the depressions which are known to cause print defects [See Figure 2]. Ruptured bubbles (holes) could be seen in two photomicrographs of print test cards.

Coating Color Rheology

Preliminary viscosity measurements were made in the Variable Pressure Viscometer on a color sample received from Continental marked **Second Coater** [See Figure 3]. In this device, data was taken at pressures of 100 kPa and 450 kPa. The flow curve roughly obeys a power law of the form

$$\tau = \beta\dot{\gamma}^{0.26}$$

at low shear rate with an increasing exponent at the higher rates (to $\sim 10^4 s^{-1}$). No effect of pressure was seen for the two pressures. However, when subambient (7 kPa) pressure was applied to the viscometer, the sample expanded into a foam most of which left the sample cup and no viscosity measurements could be made. The foam can be attributed to air in suspension in the color.

In the paper machine the average shear rate for the 6 μm thick coating at paper speeds of 4 m/s (770 fps) is $7 \times 10^5 s^{-1}$. In order to more closely simulate coating shear rates, the design and construction of a new High Shear Rate Viscometer was undertaken. The device is shown in Figure 4.

In operation the sample chamber (stator) is lowered by evacuating the chamber around the annular piston. The sample is loaded and the rotor brought to a desired rpm (20 - 2800). Upon application of gas pressure to the annular piston, the stator moves rapidly (40 ms to traverse its range of movement) upward until the stop pins are contacted. At this position the gap between the rotor and stator is as small as 36 μm . A piezoelectric load cell measures torque and normal force to give shear and normal stresses with short response time.

The new viscometer was calibrated using a newtonian fluid (bis-2-ethyl hexyl sebecate) in Figure 5. The viscosity measured is seen to be relatively flat to $3.3 \times 10^5 s^{-1}$.

Preliminary measurements on a coating color have indicated a temporary shear stress loss above $10^5 s^{-1}$. It is not yet known whether this loss is an artifact of the viscometer or the material response.

Conclusions to Date

The surface features (depressions) which produce printing defects (at least those defects revealed by the quality control test) have been defined by profilometry. Blade vibrations do not seem capable of producing these surface features. It is likely that at least some of these depressions are caused by bubbles. In light of these findings it does not appear fruitful to pursue the mathematical model coupling fluid rheological and blade mechanical responses.

More likely origins of the printability problem are void formation in the drying coating color or surface roughness of the underlying paper prior to coating.

A new viscometer for measuring coating color rheology has been completed and has been shown capable of viscosity measurements to $3 \times 10^5 s^{-1}$.

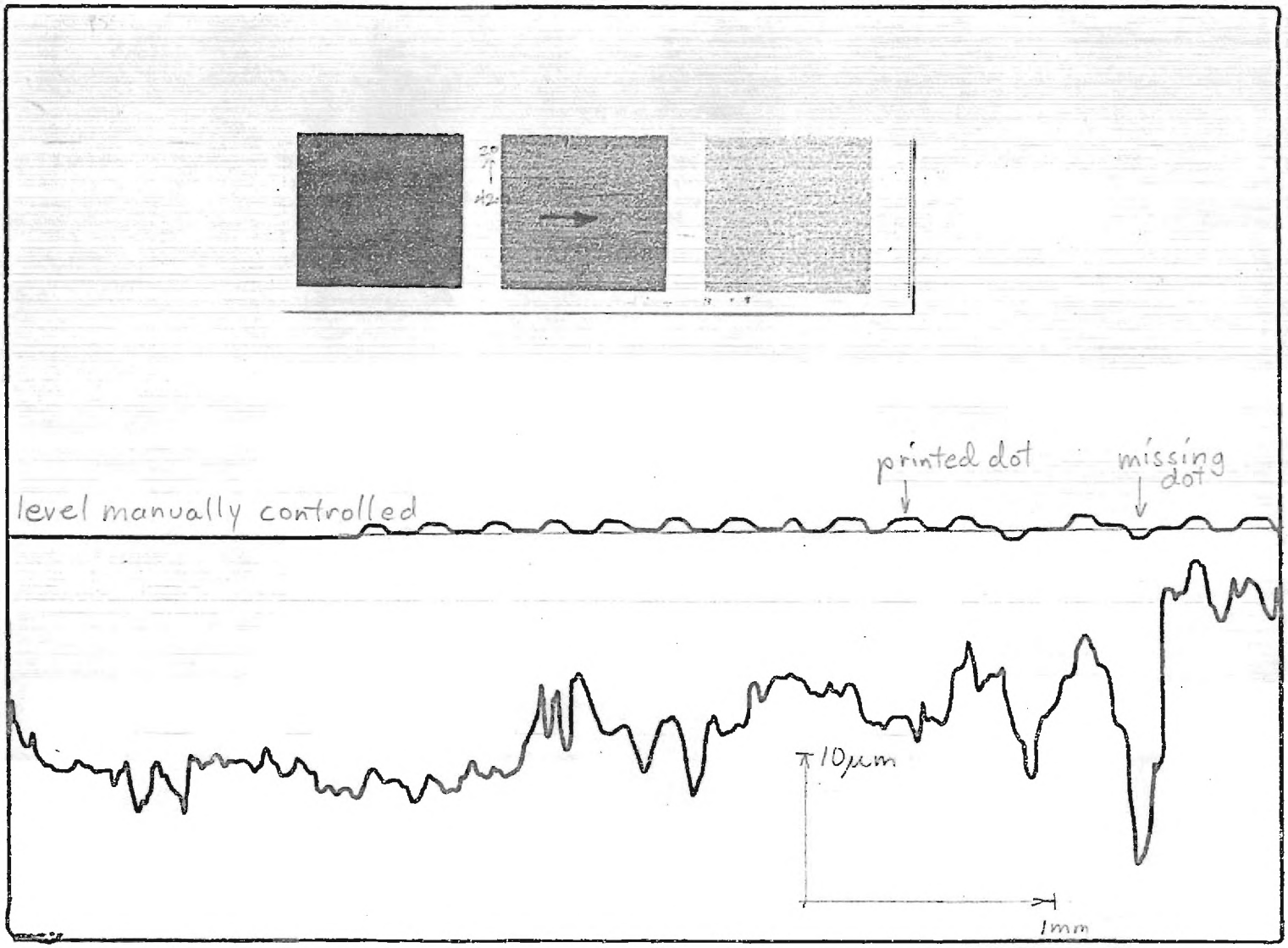

Figure 1. Coating Test Card Profile

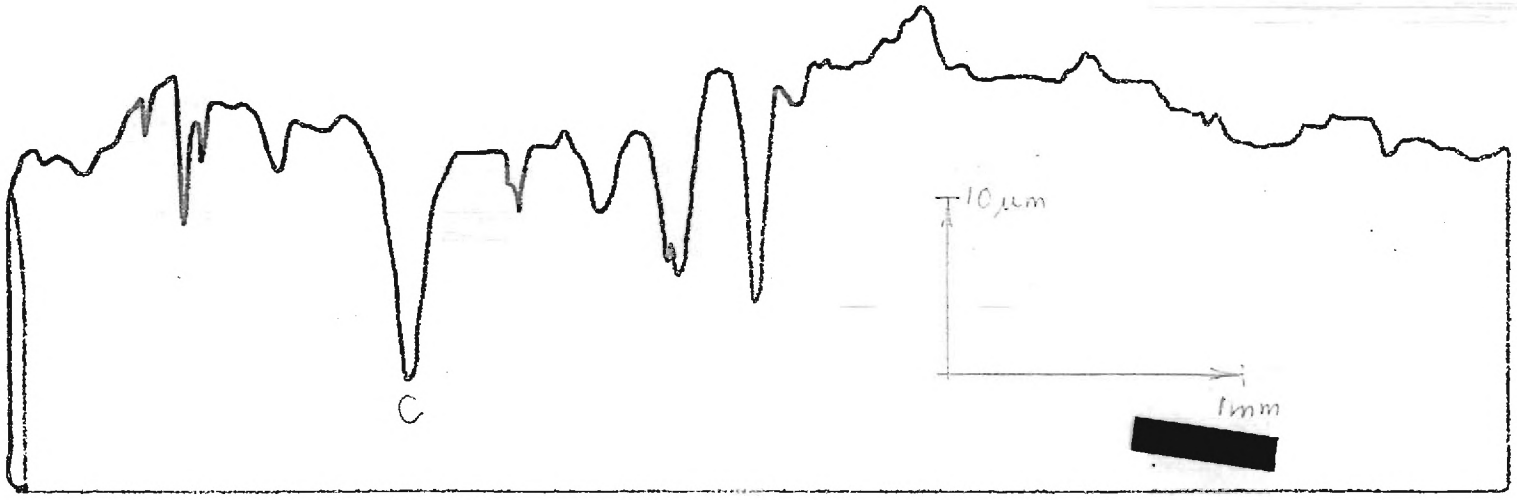

Figure 2. Slide Coating Profile. Video taped bubble marked "C". Other bubbles visible.

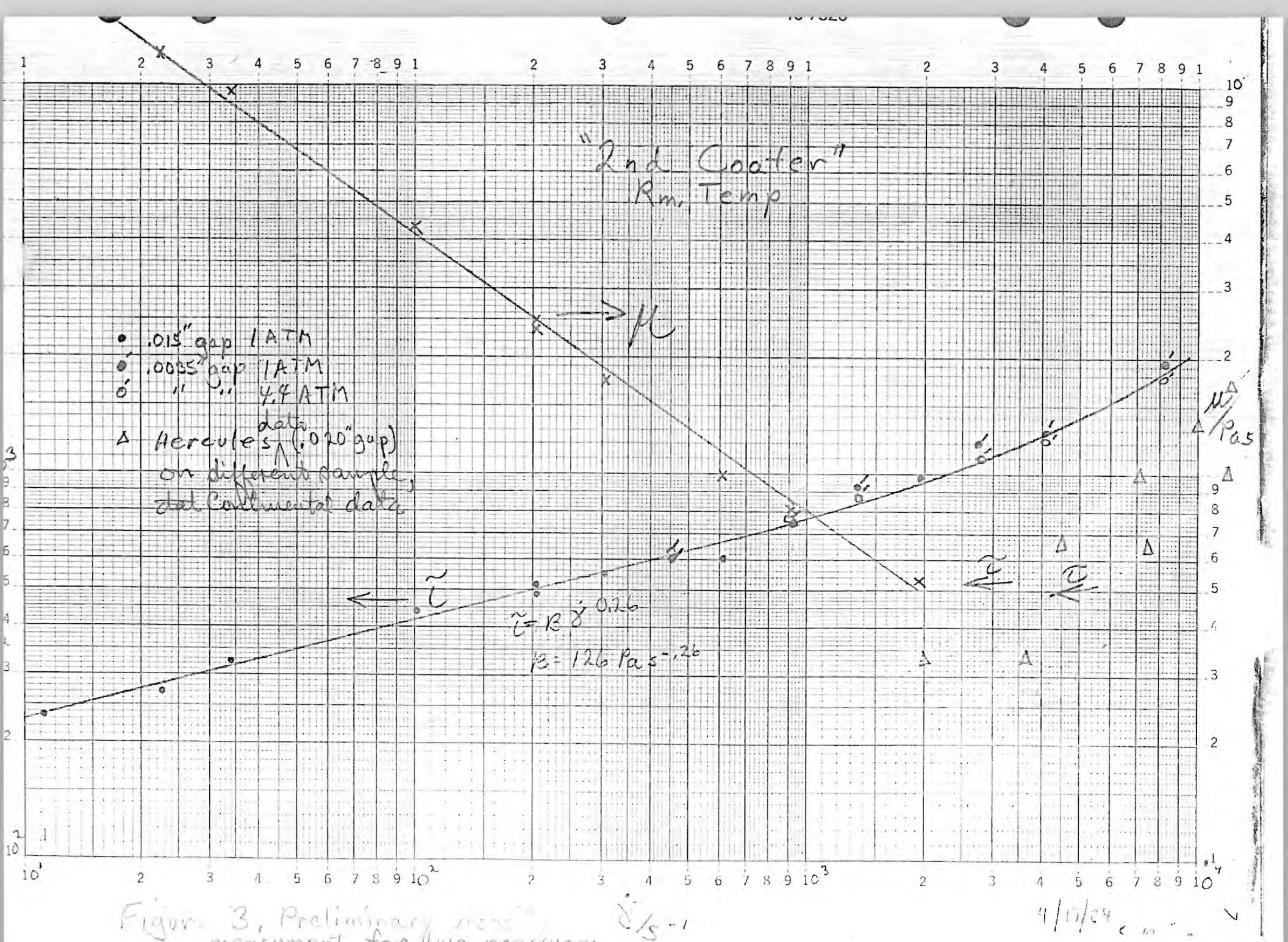

Figure 3. Preliminary rheological measurement for two pressures

9/10/84

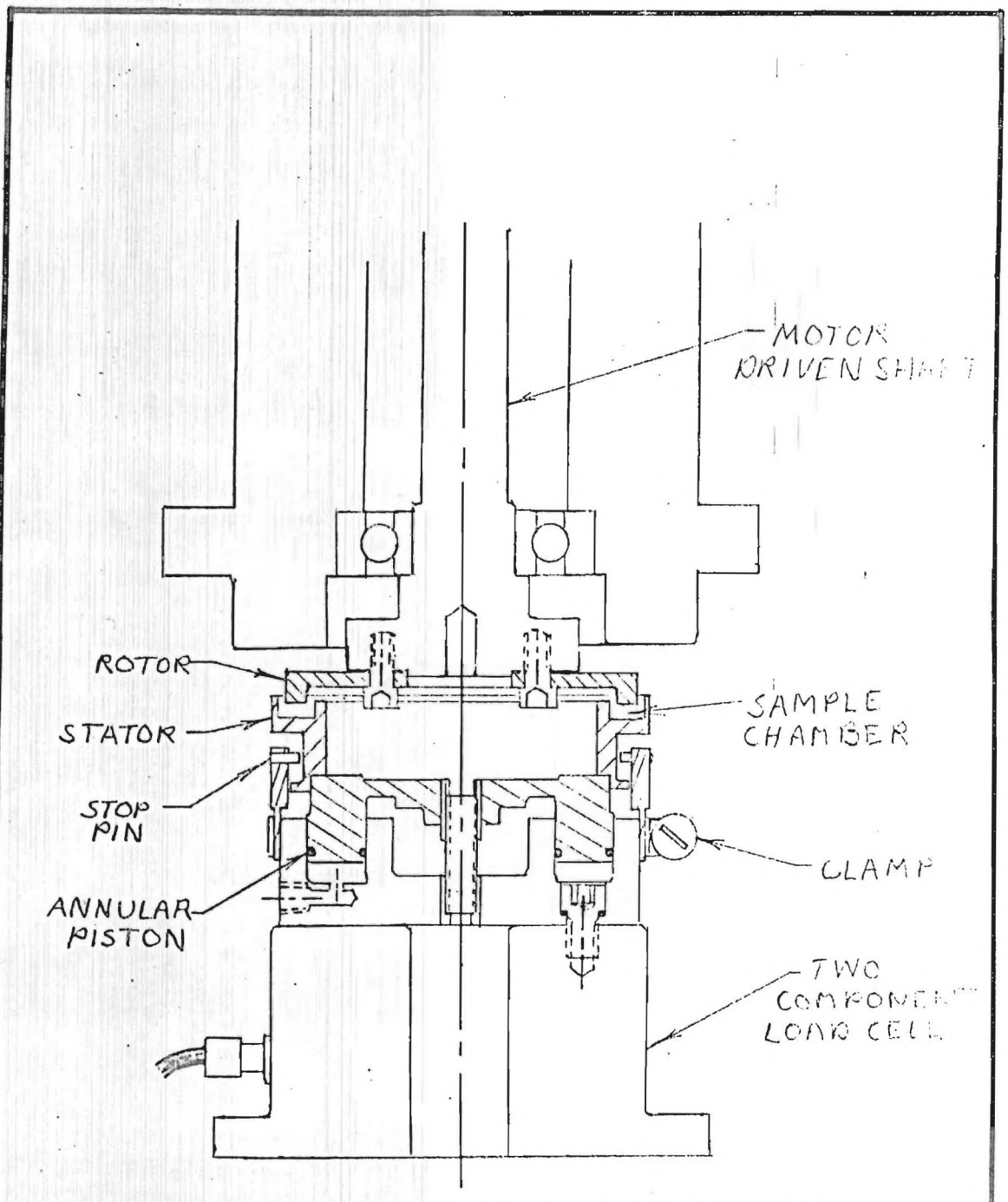

Figure 4,
Continental / Ga. Tech. Rheometer

INITIALS	DATE	TRIBOLOGY & RHEOLOGY LABORATORY SCHOOL OF MECHANICAL ENGINEERING GEORGIA INSTITUTE OF TECHNOLOGY
	July, 1984	

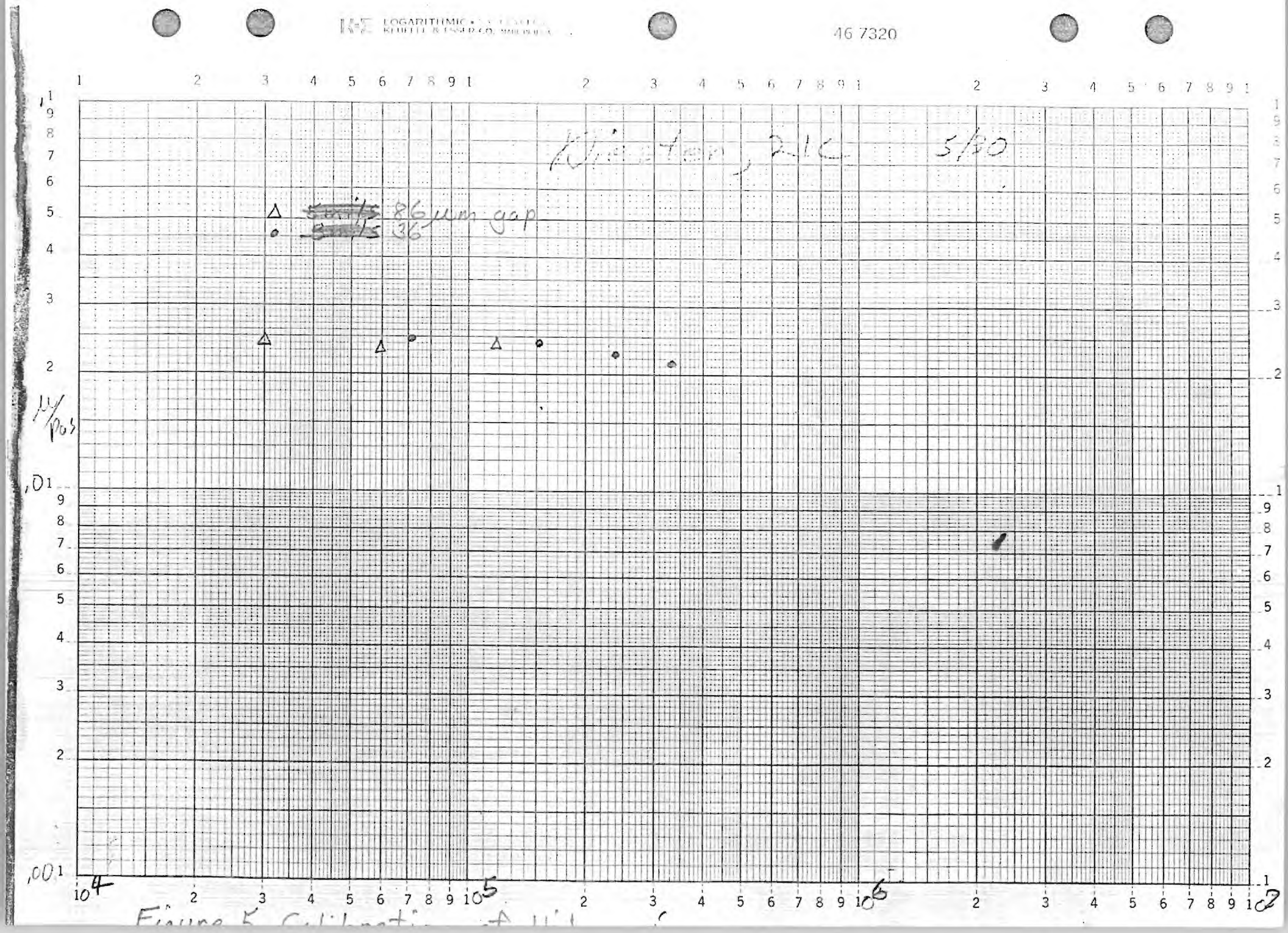

Figure 5 Calibration of Hi